Moderate Resolution Imaging Spectroradiometer

The MODIS OCEANS Quality Assurance Plan

Version 2.0

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Prepared by :

Katherine Kilpatrick
University of Miami/RSMAS
Under the guidance of Dr. Bob Evans and MOCEANS team members

KKilpatrick@rsmas.miami.edu

Contents

1.0 INTRODUCTION

This document describes version 2.0 of the MODIS OCEANS (MOCEAN) quality assurance plan. The plan incorporates experiences gained with run-time and post runtime QA for CZCS global processing, SeaWiFS, and AVHRR SST Pathfinders (SeaWiFS Technical Report; NASA Tech, Memo, 104566,Vol.13)

EOS data quality will be ensured through quality assurance, calibration and validation activities. The EOS data quality panel has stated that the objective of quality assurance is to identify and flag data products that obviously and significantly do not conform to the expected accuracy for the particular data product type. The MODIS OCEANS (MOCEAN) quality assurance (QA) plan is not concerned with calibration or validation, although it is recognized that these activities may be related to QA.

1.1 Scope

This document provides an overview of the MOCEANS data processing system and the MOCEAN standard data products before describing the MOCEAN QA plan. The MOCEAN QA plan is divided into two sections discussing:

MOCEAN QA operations

Storage of MOCEAN QA parameters

These are followed by a short summary.

1.2 Related Documents

Management Plan for the Modis Land Data Operational Product Evaluation (LDOPE) facility, Version 1.2, August 15,1997, David Roy and Robert Wolfe, NASA GSFC, Code 922

The MODIS Land Quality Assurance Plan, Draft Version 1.2,Feburary 1997, David Roy, NASA GSFC, Code 922

EOS Data Products Reference Guide, Volume 1 TRMM & AM-1, Draft Version, ESDIS Project Scientist Office, Editors S.W.Wharton and M.F.Myers, 1995.

Interface Control Document between EOSDIS Core System (ECS) and Science Computing Facilities (SCF), EOSDIS Core System Project, ICD 505-41-33, January 1996.

Release B Science Data Processing Segment (SDPS) Database Design and Database Schema Specifications for the ECS Project, 311-CD-008-001 (Formerly 311-CD-002-005), EOSDIS Core System Project, May 1996.

Software Requirements Specification for the ECS Quality Assurance Metadata Update Utility, Draft Version, Jim Closs, ECS, August 27th, 1996.

The QA Process: A Decomposition of Functional Elements Version 2, Bob Lutz, ESDIS Science Office, and March 15th, 1996.

SeaWiFS Calibration and Validation Quality Control Procedures, ed. S.B Hooker and E.Firestone, SeaWiFS Project Technical Report Series Vol. 38.

SeaWiFS Calibration and Validation Plan, ed. S.B Hooker and E.Firestone, SeaWiFS Project Technical Report Series Vol. 3, Sept. 1992.

Case Studies for SeaWiFS Calibration and Validation, Part 1, ed. S.B Hooker and E.Firestone, SeaWiFS Project Technical Report Series Vol. 13,Jan. 1994.

Case Studies for SeaWiFS Calibration and Validation, Part 2, ed. S.B Hooker and E.Firestone, SeaWiFS Project Technical Report Series Vol.19.

2.0 MOCEAN OCEAN PROCESSING SYSTEM

MODIS is planned for launch on board the EOS AM-1 platform in June 1998. MODIS will acquire Earth observations in 36 spectral bands spanning the visible and infrared spectrum from 0.415 to 14.235 ?m at spatial resolutions of 250, 500, and 1000 m. Although it is only one of five facility instruments on the AM-1 platform, the volume of data products from MODIS will exceed the output of the other four instruments combined.

The functional design of the MODIS data processing system under EOSDIS is based on processing raw MODIS data into a hierarchy of increasingly refined data products. Different levels of MODIS data product are defined:

Level 0	Instrument data at original resolution time order-restored, with duplicates removed.
Level 1A	L0 data, reformatted with calibration data and other ancillary data included. Geolocation information for each 1-km spatial element of the reformatted data are stored as a separate product.
Level 1B	L1A data to which radiometric calibration algorithms have been applied to produce radiance or irradiance at the original instrument resolution.
Level 2	Geophysical parameter data retrieved from the L1B data by application of geophysical parameter algorithms. Retrieved data are at the same location and resolution as the L1 data.
Level 3	Earth-gridded L2 data, which have been averaged, resample, or otherwise rectified or composites in time and space.

Level 1A (L1A) and geolocation software are written by the MODIS Science Data Support Team (SDST) and the Level 1B (L1B) software are written by the MODIS Characterization Support Team (MCST). The MOCEAN Level 2 (L2), and Level 3 (L3) software are developed by the science team members at MOCEAN Science Computing Facilities (SCFs). All Level 2 and Level 3 algorithm code is generated at the RSMAS SCF, which functions as the interface to SDST. Individual software processes are delivered to the SDST for integration and system-level testing at the MODIS Team Leader Computing Facility (TLCF) and are then delivered to the MOCEAN Distributed Active Archive Center (DAAC). The MOCEAN

DAAC is the Goddard Space Flight Center DAAC. The Level 3/4 Ocean Primary Production algorithm code is generated at the Ocean Primary Production SCF (W. Esaias) and delivered to SDST for integration and test, as above.

3.0 MOCEAN STANDARD DATA PRODUCTS

The MOCEAN standard data products include 40 products comprised of 4 sea surface temperature and 36 ocean color products. The sea surface temperature products include a L2 1km and L3 4km resolution product for each day and night.

The 36 Ocean color variables have a 1km resolution at L2 and are stored in 3 files. Ocean color L3 daily products have a 4km resolution and are stored in 36 separated file, one for each parameter. The L3 Ocean Color daily products fall into two groups at L3; water leaving radiance and other optical parameters, and 23 bio-optical parameters (photosynthetic pigments, dissolved organic matter, absorption and attenuation coefficients, etc.) derived from the radiance data. These bio-optical parameters will contribute to an improved understanding of global carbon cycles, and biogeochemical cycles. The ocean primary production product is produced at weekly intervals at 4 km resolution.

Short descriptions of the MOCEAN standard data products can be found at:

http://modarch/MODIS/results /results.html

Detailed descriptions of the product algorithms can be found at:

http://spso.gsfc.nasa.gov/atbd/modistables.html

The MOCEAN SCF estimates that the daily averaged production capacity of the MOCEAN standard data products will be approximately 200 GB. These products will be produced at MODAPS and transferred to the Goddard Space Flight Center DAAC for archiving and distribution.

The MOCEAN standard data products are stored in hierarchy data format (HDF) and are composed of science data sets (SDS) and metadata. Their size is driven by the need to keep storage volumes within the allowable 4 GB maximum of a 32-bit addressable UNIX operating

system and the 2 GB limit of HDF files. The smallest amount of MOCEAN data processed at any one time is defined at L1 and L2 as a granule and at L3 as a day. A granule corresponds to 5 minutes of MODIS sensing. There are up to 1000 MODIS 1 km detector scan lines and 100 scans[1] in a granule. Each MODIS scan line is composed of 1354 1 km (at nadir) pixels. Because of the curvature of the Earth and the MODIS scanning geometry the scan lines are elongated so that the geographic coverage of a granule is approximately 1000 x 2330 km. L3 gridded data products are processed in fixed, non-overlapping, earth-located bins rather than granules. Each bin will have dimensions of approximately 4.63 x 4.63 km. There are 20 million ocean bins globally. In addition to level 3 binned datafiles mapped products will also be produced that have a significantly reduced file size. The smaller mapped products will be available at space resolutions of 4km, 36km and 1 degree and time resolutions of days, weeks, months, and years.

4.0 MOCEAN QUALITY ASSURANCE

MOCEAN QA procedures will be performed operationally after product generation at the MODAPS (processing context QA) and some period after product generation at the MOCEAN SCFs (science context QA) and at a MOCEAN QA facility (post processing science QA and long term validation QA).

Processing context QA results will be derived after product generation by:

1) Analysis of selected L2 granules
2) Examination of the input data and its associated QA data.
3) Monitoring the computational stability of the code.
4) Documentation of the code processing history.
5) Science decision making performed within the code.
6) Application of visual analysis of a selection of 40 daily L3 products.
7) Comparison of L3 products to climatologies when available.

Science context QA results will be derived by:

1) Application of visualization and statistical analysis procedures to generated products.

[1] MODIS is a paddle wheel sensor that simultaneously senses 10 rows of 1km detector pixels as the scan mirror sweeps across track. A scan, or swath, is composed of 10 scan lines of data.

2) Examination of pixel level QA results stored in generated data products.
3) Analysis of temporal, zonal, meridianal, secular, and regional tends of L3 generated products.

Validation QA results will be derived by:

1) comparison of L3 products to *in-situ* observations
2) long term trend analysis of the L3 products
3) cross validation studies with SeaWIFS and AVHRR data
4) algorithm development

The results of QA procedures will be stored within the MOCEAN standard data products following a MOCEAN protocol described in Section 6.0. MOCEAN QA procedures will focus on analysis of pixel level flags (see Section 6.o) which contain science and quality level information. Granule level summary QA statistics (QA PERCENT INTERPOLATED DATA, QA PERCENT MISSING DATA, and QA PERCENT OUT OF BOUNDS DATA) are not relevant to MOCEAN QA procedures. Results of MOCEANS science QA analysis are communicated at the granule level through frequent updates to the mandatory ECS QA metadata (SCIENCE QUALITY FLAG, QUALITY FLAG EXPLANATION). The text based flags are written *after* product generation. Science context QA procedures will be performed by analysis of both the MOCEAN products produced at the SCF and those produced at MODAPS when a processing context QA procedure fails at a specified level.

The MOCEAN QA results will be used in the following ways:

?? by MOCEAN algorithm developers :
  - To ensure that their algorithms check QA parameters stored in MOCEAN data products read by the algorithm.
  - To examine the QA data produced by their algorithms in order to check the correct functioning of the algorithm code and to make inferences useful for future algorithm development.
  - To assist in post-launch validation and calibration activities.

?? by Processing Center personnel who may inspect QA summaries to check the operational functionality of the configured MOCEAN codes.

?? by MOCEAN personnel performing post processing QA.

?? by MOCEAN data product users :
  - Who may examine the product QA for data selection/browse.

- Who may use QA to make discoveries (e.g. volcanic eruptions).
- For developing error budgets in their own procedures and analyses.

5.0 MOCEAN QA OPERATIONS

The routine examination of MOCEAN data products will be time consuming, complex and difficult to manage. This is because of the large number of MOCEAN products, the data dependencies that exist between them, the distributed nature of the MOCEAN algorithm developers and because different post processing QA procedures will be applied to different spatial and temporal samples of data. Consequently a QA facility, the MODIS Ocean Data Assessment Team (MODAT), has been formed to provide a coordination mechanism for MOCEAN's QA activities.

MOCEAN QA is performed in a multi-step process, using an initial triage approach. The first step in examining the data is Processing run-time QA. In this first step, global products are briefly viewed at coarse resolution to identify missing data and gross scientific problems. Large regions of poor quality data are identified and logged into the QA database and MODAT is alerted directly by e-mail of any serious production problems. In this first step the production stream is also monitored for failed PGE's and to ensure that all possible granules are produced. The next step is a more detailed Scientific QA performed by the MODAT team. The poor quality data granules identified during Processing QA procedures are analyzed in more detail using pixel level information. Routine statistical analyses are performed on all granules produced and temporal and spatial trends are investigated. Results from both the Processing and Science QA analysis for each granule produced at MODAPS is stored and tracked by MODAT using the MOCEANS QA database (web access at http://miracle.rsmas.miami.edu/qadb.html). Finally, using the information stored in the MOCEANS QA database the MODAT periodically makes an assessment on the overall quality of each of the data granule or product in conjunction with the appropriate MOCEAN team member. This information is added to the QA metadata of the data file via updates to the QA flag and QAflag explanation found in ECS inventory metadat a for the granule. Lastly, algorithm scientists perform detailed longer term Science QA on their own data products. Upstream products are analyzed, algorithms are refined and selected sites are validated against *in situ* measurements. This Science QA is an on-going task, and results in improved algorithms and assessment of overall algorithm uncertainty levels.

The MOCEAN QA procedures are performed at MOCEAN SCF's and MODAPS by MODAT personnel. The communication between the GDAAC, MODAPS, MOCEAN SCF's and MODAT and their roles within the MOCEAN QA process are considered in detail below.

5.1. Communication between the GDAAC, MODAPS and MODAT

The data and information flows required for the MOCEANS QA strategy are shown in Figure 1.

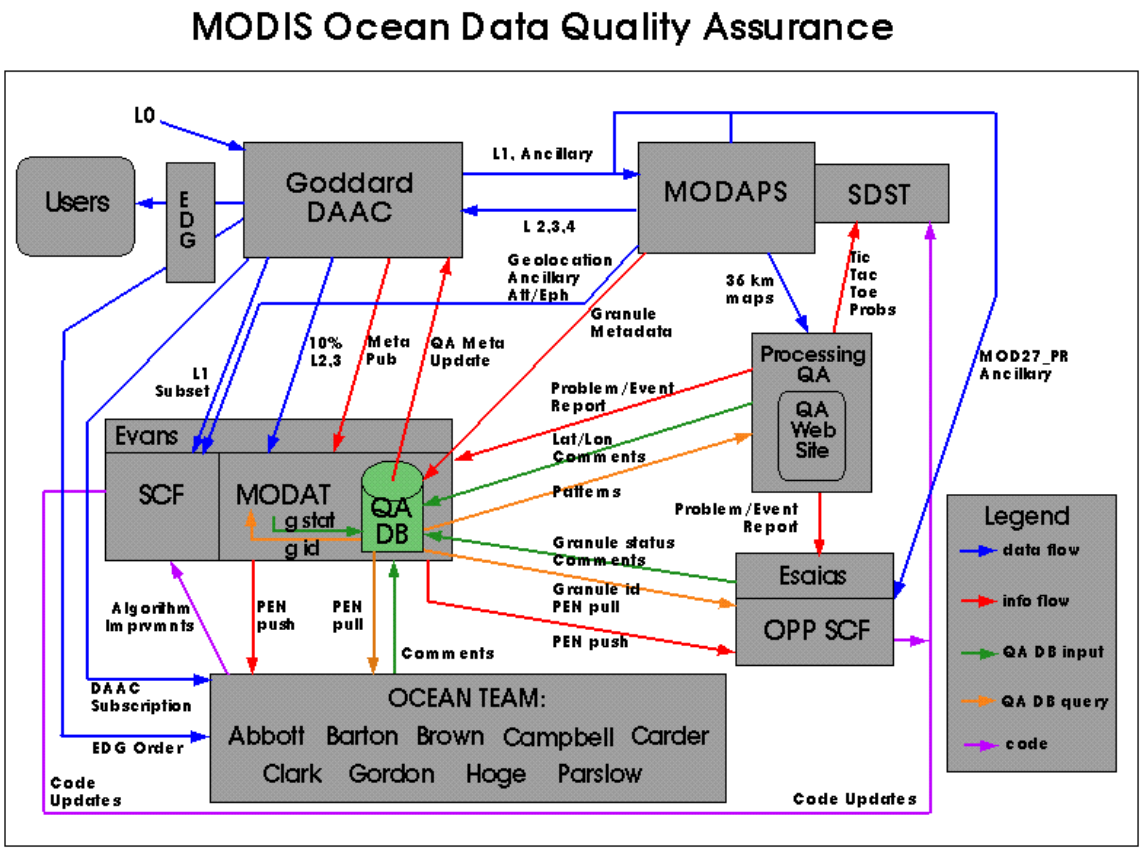

Figure 1. Oceans QA information flows

Data Ordering and subscriptions:

The RSMAS SCF is the central coordination point for MODAT and receives data products from several sources including the GDAAC, MODAPS, and performs local processing for QA procedures. The details on the current operational data ordering and subscription options available to the OCEAN team member SCFs for at-launch QA activities can be found at http://modis-ocean.gsfc.nasa.gov/qa/orderoptions.html. Below we outline the various procedures for obtaining data for QA purposes. Some of these options are not currently available but are scheduled to complete testing and integration for operational use in the near future.

When a granule/daily product of MOCEAN data is inserted at the GDAAC the metadata is copied into the EOSDIS database. During this process SCF/MODAT defined subscription criteria are compared with the metadata. If the subscription criteria are satisfied the GDAAC will send a subscription trigger notification to the appropriate SCF and automatically push the requested data from the GDAAC to the SCF.

Subscriptions and standing order data requests to the GDAAC will originate from the RSMAS SCF, MOCEAN team institutions as well as the MODAT processing QA member located at MODAPS:

-MODAT processing context QA at MODAPS

Processing context QA requires subscription via MODAPS to all 36km interim maps of L3 MOCEAN products. Optimally the MODAT personnel would QA all 40 products for each time resolution. Due to the anticipated limited bandwidth for data transfer and time constraints of examining all the products produced in a day, the MODAT personnel at MODAPS may alternatively QA a subset of L3 map data to ensure that each of the 40 products are QA'ed at least once per week.

The MODAT member responsible for processing QA also monitors production for Failed PGE's via the MODAPS ocean tic-tac-toe production reports (http://mtvs1.nascom.nasa.gov:8001/report/beta/ocean.cgi). In the event of a failed PGE the MODAT representative will order from the MODIS Emergency Backup Data Ordering System (MEBDOS) all processing logs associated with a failed PGE. If needed these logs maybe pushed to MODAT members at the MOCEANS RSMAS SCF who will examine the processing log and use data ordering tools to obtain the required input files from the GDAAC or MEBDOS to further investigate the problem. Processing context QA will analyze all data associated with a failed PGE to determine if the failure was operational or science related. Processing related problems will be directly report to SDST via e-mail and science code problems will be reported to RSMAS SCF for resolution.

-MODAT science context QA located at the RSMAS SCF

Science QA requires L1A, geolocation, ancillary, and orbital data at the MOCEANS RSMAS SCF for parallel processing and algorithm development. Due to the large volume of data ~130GB per day the MOCEANS SCF has arranged for the GDAAC to produce L1A files which contain a subset of 24 L1A bands (MOD01ss). The following MODIS bands 5-16, 20, 22, 23, 26, 27, 29, 32 are

included in these reduced sized files. All other bands are set to zero which when compressed produces a much reduced files size. These files when expanded execute properly through the RSMAS SCF local processing chain. To further decrease the data transfer volume, the MOCEAN RSMAS SCF will create the geolocation files locally using a dedicated workstation. The RSMAS SCF has obtained copies of the PGE code (MOD_PRO3, MOD_PRO2) required to make these files. The MOCEAN RSMAS SCF is currently obtaining the reduced L1a, ancillary and ephemeris data by subscription from the GDAAC. The bandwidth between the DAAC and RSMAS SCF is estimated to be approximately 5GB/day for T1. Abilene related network changes have recently been implemented at the RSMAS SCF and the data rate from GSFC is on the order of 1mbyte/sec.

- Post run-time science and validation QA by each member of the MOCEAN's Science Team

Each of the MOCEAN team members will subscribe to a portion of their respective L3 products for daily review of processing correctness and reasonable data values, but not validation. Each global product produced is ~700MB for the 4km L3 binned product. These L3 binned files contain all the data and flags for a given parameter. Due to bandwidth and load limitations some team members may subscribe to4km mapped product s. Eight separate maps are available for each product (means, standard deviations, counts, common flags, quality flags, and 3 product specific flags). These mapped fields are ~200MB/ product and are available for several time resolutions (days, weeks, months, and years). For Team members still limited by bandwidth, reduced resolution of 18km, 36km, and 1 degree are also available by subscription. For validation QA team members will use data ordering tools to obtained archived products from the DAAC as needed for specific locations and times.

The long term goal of MOCEANS QA is to perform science QA on each product/granule. QA of this many granules is feasible as a combination of computer checking of granules at several SCFs and implied QA of level 1 and 2 products when L3 images undergo manual QA. Implied QA of lower level products is standard procedure within the SeaWiFS project and

expected within the MODIS Ocean Discipline Group. When a L3 image is given a clean bill of health then the L2 products that went into making the L3 product are assumed to be OK. As experience is developed at the SCFs with particular products patterns of failures will become apparent and automated tests can be developed to look for these specific types of algorithm failure. This allows large numbers or potentially all of the granules to be checked for these known problems. When patterns of algorithm failure are detected eventually improved production algorithms will be implemented. Some granule wide QA procedures are expected to be semi-automated approximately 6 months posts launch and follow the general outline given below.

1. A running climatology produced by MODIS/AVHRR/SEAWIFS will be compared to the respective MODIS granule. This activity is likely to be on the order of one month behind real-time to permit assembly of the needed climatology.

2. Where feasible, the MODIS granule will be compared with the expected values and placed into a reasonable/unreasonable category. The range of conditions that can be tested is expected to grow with time. As experience grows, we should be able to characterize product algorithm, sensor, and calibration accuracy.

3. Large numbers of granules are involved and we eventually anticipate updating the QA metadata on tens of thousands of granules per month. The list of granules to be updated is transmitted to the GDAAC in a formatted e-mail message. Authorized GDAAC personnel authentic the origin of the message and submit the list to the QA update tool. MODAT uses MOCEANS QA database transaction procedures to create the required information and list of granules in the required formats for the bulk QA update. These bulk updates are performed on time scale of weeks to months. Multiple updates to the same granule are expected as our experience with the sensor grows.

5.2 Role of MODAPS and GDAAC

The MODAPS personnel will ensure the quality of the operational data production process but they will not perform extensive QA of the MOCEAN products. MODAPS and SDST personnel may check the operational functionality of the configured MOCEANS codes and ensure the correct functioning of the data production process and the availability of production logs to ensure that the data products remain uncorrupted during production and transfer to GDAAC. The GDAAC is responsible for the operational production and export of Level-1 data to the processing centers, archive and retrieval of higher level products, and ensuring the integrity of the EOSDIS database.

5.3 Role of the MOCEAN SCF's

The science team members at their own SCF are formally responsible for the QA of their data products. SCF personnel may monitor data product generation, order data from the GDAAC, receive data from the GDAAC via subscription, and apply post run time QA procedures to the data. SCF generated QA results will be sent to the MODAT QA database for communication to the GDAAC where they will be written to the SCIENCE QUALITY flag in each granule/tile of data examined.

Until the MOCEAN data production system is stable the science team members may wish to perform daily post run time processing QA of their data products. However, a MODAT member at the RSMAS SCF will routinely perform this task. The SCFs will receive weekly written summary reports from the MODAT manager informing them of the general status of granules/products in the QA processing stream. These reports may be sent to the SCF's via e-mail if requested and are posted to the Oceans QA web page (http://modis-ocean.gsfc.nasa.gov/qa. Investigation of non-trivial errors detected by the MODAT will be carried out cooperatively by RSMAS SCF and MODAT personnel. The RSMAS SCF personnel may perform their own investigations and expert QA at any time and will seek to rectify the cause(s) of error (most likely by updating the product generation algorithms).

The RSMAS SCF personnel will provide MODAT personnel with copies of their product specific QA tools and any relevant training that is required. The RSMAS SCF personnel will inform the MODAT personnel of QA results generated at the RSMAS SCF and will advise the MODAT personnel of appropriate QA subscription notices, algorithm updates and scientific findings that may influence the quality of their data products.

5.4 Role of the MODAT

The MODAT is integrated with the MOCEAN science team and works for the team to provide a coordinated MOCEAN QA facility. The MODAT personnel will perform routine day to day QA of select MOCEAN products consistent with the ability to access products (i.e. bandwidth), investigate QA failures, and seek to make recommendations to the MOCEAN science team members to improve the quality of their data products.

The MODAT is a small group of technical and scientific personnel located at the RSMAS SCF, and MOCEAN team member institutions:

- a manager located at the RSMAS SCF
- 1 analyst located at the MODAPS GSFC processing facility
- 2 personnel located at the RSMAS SCF; 1 scientist and 1 programmer analyst
- 5 scientists located at MOCEAN team member institutions (Univ. of Southern Florida, Oregon State Univ., GSFC (Hoge & Esaias), and NOAA (D. Clark).

The MODAT manager is located and provided by the RSMAS SCF and is directly responsible to the MOCEAN science team. An additional MODAT members located at the RSMAS SCF is a programmer/analyst whose role is to develop, manage, and improve MODAT QA tools including the MOCEANS QA database. The scientific personnel responsible for post run-time

science QA will be provided by the MOCEAN science team members and will be located individually at the member's institution.

The MODAT personnel will spend no more than half their time performing routine visualization tasks and supervising automated QA procedures. The remainder of their time will be spent investigating specific problems found during the routine QA. This division of labor may change. Immediately post-launch the majority of effort will be expended investigating specific problems.

MODAT personnel will monitor data product generation, order data from the GDAAC, receive data from the GDAAC via subscription, and routinely apply post run time QA procedures to samples of the MOCEAN data products. MODAT QA results will be sent to the GDAAC where they will be written to the SCIENCE QUALITY flag in each granule/daily product examined. The MOCEAN science team members will define the product specific QA procedures performed by the MODAT. Generic QA procedures will be developed by MODAT personnel at the RSMAS SCF.

MODAT personnel are responsible for the dissemination of information to the RSMAS SCF concerning the causes and potential fixes of QA failures detected by MODAT. Information concerning relevant slips in the MODAPS production schedules is also disseminated. This information is sent to the RSMAS SCF directly and is made available to the wider user community via the MOCEAN QA web page.

When a MODAT member detects a non-trivial error they will contact the MODAT manager to initiate a Problem Event Notification (PEN). The MODAT manager will then coordinate further investigation of the error to be carried out by MODAT members in conjunction with the RSMAS SCF and science team member.

5.5 Role of MODAT members and QA data volumes and sampling

MODAT Processing context QA

The role of the MODAT representative responsible for processing context QA is to monitor production of ocean products and associated production rules. This member will check for completeness of the level 2, and level 3 production by visual examination of level 3 daily map products. All MOCEAN standard data products will have processing context QA performed for each pixel in the L3 product generation code. The MODAT personnel will attempt to routinely analyze a feasible amount of the daily averaged data volume of MOCEAN L3 products. At "first light" if it is not possible to examine all L3 products each day the MODAT representative may optionally examine key level 3 daily products (i.e. SST, chlorophyll, nLw) and perform visual analysis on remaining products once per week. Each day the processing QA results for all granules examined are sent via e-mail to MODAT at the RSMAS SCF for upload into the MOCEANS QA database. Monitoring the MODAPS processing tic-tack –toe production chart, identifies missing granules and failed PGE's in the production stream. The MODAT personnel at MODAPS report observed anomalous conditions to the MODAT manager and SDST. When processing QA procedures observe a Failed PGE or large numbers of missing granules, personnel will order logs and other input granules/products as needed to determine if the failure is a science processing system problem.

Evolution of responsibilities of the MODAT member s responsible for processing QA is anticipated to move toward zero-order science QA tasks approximately 6 months post-launch. These tasks may include the following:
Semi-automated checks and trending performance of pixel level QA and metadata summary flag performance and values. Checks of data consistency with climatology for major regional shifts in the product. Examination for ephemeral events such as red tides, toxic blooms, dusts, volcanic eruptions which maybe affecting performance. This may require comparison/correlation with other MODIS products or AM-1 products.

MODAT at SCF Team member institutions (post run time science QA)

Post run time science QA procedures will be performed periodically at the RSMAS SCF and will be performed systematically by MODAT members at the RSMAS SCF and team member institutions. The MODAT personnel will examine a regular sample of each L3 data product received under subscription or by standing order from the GDAAC to check for integrity of product transfer between MODAPS and the GDAAC by comparison to the RSMAS locally generated products. MODAT members will investigate all FAILED PGE's suspected to be due to science related problem and other granules MODAT members have identified as being suspect.

A hierarchy of post runtime science QA procedures will be defined by the MODAT with complex QA procedures applied less frequently than more simple QA procedures. Post run time science QA procedures will be applied most intensively where processing context QA failures occur and where algorithm understanding can predict expected problems. They will also be applied to a regular sample of each data product in a spatially and temporally stratified manner coincident with expected natural variations in geophysical and atmospheric phenomena. MOCEAN products will require examination of global or partial samples of the globe and time series will be extracted from some products for trending analyses.

Post run time Science QA procedures will examine both pixel and global context with the goal of understanding differences due to instrumental, code/algorithm, geophysical, and biological effects. Accomplishing this goal require s a complete set of L1a data at the RSMAS MOCEAN SCF. A primary output of this effort will be revisions in criteria and thresholds used to define and set pixel level flags, and rules for using the flags at level 2 to control acceptability for binning pixels into level 3 fields, and in establishing the confidence flags.

The pixel level flags stored in the products at the time of generation include quality flags, common flags, and product specific flags. The global context of the products will be evaluated

by comparisons with SeaWIFS andAVHRR same day retrievals, climatologies developed from MODIS and other sensors, MODIS atmosphere products, and last weeks MODIS product.

Final checks on the MODAT-SCF QA fidelity will be made by each team member by subscription of sample products from the GDAAC to assure that the "official" EOS products meet their expectations.

A coordinated end-to-end MOCEAN QA of all the MOCEANS products will be performed periodically at common locations distributed across the globe. This will be useful for resolving data dependency problems expected immediately after launch and after algorithm updates and will provide a mechanism to verify that the configured algorithms behave in the same way as the scientific algorithms. Common geographical locations will include those selected under the MOCEANS validation plan. QA long-term validation and comparison with in-situ observations will occur at the RSMAS SCF with the Match-up Data base to assign confidence/uncertainty limits of the products.

5.6 MODAT Management Issues

Routine MODAT managerial activities will be conducted using a suite of information management tools. These tools include the MOCEANA QA web page and the MOCEANS QA database. A brief outline of MODIS Oceans QA database transactions and queries developed to track results and allocate resources is given below.

MODIS Oceans QA database input transactions:

L2/L3 Metadata loader

Parses and loads L2 and L3 metadata into the oceans QA database (tables: map, L2 tables). The metadata is obtained from a MODAPS based subscription to SST metadata file files. This information is replicated for each MODAPS granule produced for ocean color. A unique granule ID must be present in the database for each file produced. During loading the dataday

for all the L2 granule ID's is included in the tables(note: each granule can be in up to 3 datadays).

QA finger

Parses and loads e-mail message from processing QA (tables: map, and qabox , gvalues tables). MODAT processing representative looks at the 36km maps for a product and sends in an e-mail the granuleID processing QA comment, box processing QA priority, corners of any problem boxes in the map and a comment for each box, and global mean value.

Comment update

Used to update and add to comment fields (tables: map, and qabox tables) for a granule. Parses e-mail message with granule ID or boxId and comments and source. (ie there is a unique comment box for each source. (map table updated)

Set/change QA flag

parses e-mail message from MODAT members with QA flag and Flag explanation for each parameter in an L2 or L granule. Requires granule ID, parameter, Qaflag,QA flag explanation and source. Procedure records the time that the QA flag is set. Will want to make a front end procedure to set the QA flags for multiple parameters and multiple data days at once. Rather than one granule at a time.(map and mod* tables). A) For L2 ganules need to be able to set flag for all the granules in the dataday at one time. Must have the ability to set l2 granules containing the problem box differently from the other l2 granules in that dataday. B) any give 36km maps type sets flag for all the daily gobal granules (ie binned) and other space resolutions (ie. 4km, 1D) based on the Qaflag for the 36km map. C) only send data for a given boxid.

ECS metadata publication loader

parses and loads ECS metadat publication files to obtain UR's of inserted granules. (table: univeral reference)

ECS QAFlag Metadata update

generates ECS metadata update message only for granules ingested at the DAAC (known from #5). Needs to find granules that have had their QA Set (#4) since last time procedure was run and prepare ECS message using UR's (#5). Records when QAflag update sent to GDAAC for each granule in the database.

ECS QAFLAG verification- parse and loads return e-mail message from DAAC indication success or failure of the QA update for the granules sent in #6.

Example of Queries to the Oceans QA database:

Qainfo

browse flags and comments for granules.

A. find high priority problems in daily files

Criteria – dataday, priorty level,parameter, or all

Returns – 36km map granID and proceeing QA comment and problem boxid latlon and comment

B. find all the L2 granules and associated comments for both the problem boxes and general comment for a given dataday.

Criteria-dataday, parameter, or all,t ype

Returns – granule ID and comments.

C. get the global mean values for some time frame

Criteria – time window,type

Return- granID begin range time and gvalue

D. find L2 for a given lat lon

Criteria – time window, lat lon box, type

Return – granID, comments

E. find a given map and get input file points

Criteria – dataday, type, parameter

Return – granID, comments , input file pointer

6.0. STORAGE OF MOCEAN QA PARAMETERS

This section describes the MOCEAN QA storage protocol. The protocol was developed to be adaptive enough to accommodate a changing QA data stream over the life of MOCEAN while satisfying the needs of the algorithm developers, personnel performing routine QA of generated products, and the data users. The protocol includes both pixel level QA results stored in science data sets (SDS) generated at the time of execution (non-searchable) and granule/product level ECS QA metadata (Science Quality flag, text explanations, QA Percent Missing) which are searchable.

6.1 Science data set QA storage

Spatially explicit run time QA results will be stored in:
?? mandatory QA SDS's

The mandatory QA SDS are defined for *all* Level 2 or higher MOCEAN products that have the same spatial resolution as the MODIS instrument i.e. 250m, 500m or 1km.

Pixel level QA parameters common to all products are:

- Common flags: 1 byte for each pixel:

Bit	Description	Result

0	Pixel not processed	0=processed, 1=not processed
1	Atmospheric Correction	0=successful,1=failed (due to atmos_corr,bad ancillary data, and/or sun glint)
2	Satellite Zenith Angle	1=too large, 0=ok
3	Solar Zenith Angle	1=too large, 0=ok
4	Shallow water	1=shallow
5	Sun_Glint - Glint > threshold	
6	Supp_Data - Invalid or missing ancillary data	
7	Land	

- 4 bytes from Cloud Mask flags

Pixel level QA parameters unique to each product

Pixel QA parameters unique for each product consist of two types; flags which contain information on specific tests, and a quality level summarizing the results of various common and product specific flags for each pixel for a given product. Below is listed the pixel quality level and science QA flags for each MOCEAN level 2 and 3 product

MODOCL2 - 3 bytes QA parameters:

-quality levels - 1 byte

bit

0-1 Mandatory Quality for all of Gordon's nLw bands:

0 (good) if general bits are ok, and flag bits 1-12 are ok

1 (questionable) if any of: shallow, large zenith angles, or flags 9-12

2 (cloud) if any input radiances are negative and saturated

3 (bad, other than cloud) if any input radiances (all 9) are negative and not saturated, or Atmos Corr (bit 1 above) failed, or land

2-3 Mandatory Quality for Carder's clear water epsilon band

0 (good) if general bits are ok, and input Lw's are ok, and flag 14 ok

1 (questionable) if any of: shallow, large zenith angles, or flag 14

2 (cloud) if any input radiances are negative and saturated

3 (bad, other than cloud) if any input radiances are negative and not saturated, or Atmos Corr (bit 1 above) failed, or land

4-7 Spare

-flags - 2 bytes

bit

0 Cloudy - Albedo @ 865 > threshold 1=cloudy 0= clear

1 Bad_Lw - One or more bands missing

2 Bad_Lw - Any LwXXX <= 0.

3 Bad_Lw - Any band counts < 0

4 Atmos_Corr - Questionable polarization correction/mirror reflectance

5 Atmos_Corr - Gordon aerosol failure

6 Atmos_Corr - Epsilon out of range (< lower limit or > upper limit)

7 Atmos_Corr - Any LaXXX <= 0.

8 Atmos_Corr - Invalid Raleigh scattering data

9 nLw550_low - Calculated nLw550 is too small

10 Cocco - Coccolithophorid radiance exceeds threshold

11 TurbidCase2 - Actual_rrs555 > Turbid_rs555

12 Hi_la865 - Calculated La865 is too large

13 input Lw's for Carder's clear water epsilon band (11,13) are ok

14 lo_eps - epsilon < threshold

15 absorbing aerosol 1=present 0= absent

MODOCL2A - 6 bytes of QA parameters:

-quality level - 3 bytes

Bits

0-1 Mandatory Quality for Clark's pig_c band

0 (good) if general bits are ok, and input Lw's are ok

1 (questionable) if any of: shallow, large zenith angles

2 (cloud) if any input radiances are negative and saturated

3 (bad, other than cloud) if any input radiances are negative and not saturated, or Atmos Corr (bit 1 above) failed, or land

2-3 Mandatory Quality for Clark's pig_total and chl_modis band

0 (good) if general bits are ok, and input Lw's are ok

1 (questionable) if any of: shallow, large zenith angles

2 (cloud) if any input radiances are negative and saturated

3 (bad, other than cloud) if any input radiances are negative and not saturated, or Atmos Corr (bit 1 above) failed, or land

4-5 Mandatory Quality for Clark's susp_solid band

0 (good) if general bits are ok, and input Lw's are ok

1 (questionable) if any of: shallow, large zenith angles

2 (cloud) if any input radiances are negative and saturated

3 (bad, other than cloud) if any input radiances are negative and not saturated, or Atmos Corr (bit 1 above) failed, or land

6-7 Mandatory Quality for Clark's k490 band

0 (good) if general bits are ok, and input Lw's are ok

1 (questionable) if any of: shallow, large zenith angles

2 (cloud) if any input radiances are negative and saturated

3 (bad, other than cloud) if any input radiances are negative and not saturated, or Atmos Corr (bit 1 above) failed, or land

8-9 Mandatory Quality for Abbott's fl_baseline band:

0 (good) if general bits are ok, and input Lw's are ok, and 7-11 are ok

1 (questionable) if any of: shallow, large zenith angles, or flags 7-11

2 (cloud) if any input radiances are negative and saturated

3 (bad, other than cloud) if any input radiances are negative and not saturated, or Atmos Corr (bit 1 above) failed, or land

10-11 Mandatory Quality for Abbott's FLH bands:

0 (good) if general bits are ok, and input Lw's are ok, and 7-11 are ok

1 (questionable) if any of: shallow, large zenith angles, or flags 7-11

2 (cloud) if any input radiances are negative and saturated

3 (bad, other than cloud) if any input radiances are negative and not saturated, or Atmos Corr (bit 1 above) failed, or land

12-13 Mandatory Quality for Abbott's Chlor Fluorescence efficiency band:

0 (good) if general bits are ok, and input Lw's are ok, and 7-11 are ok

1 (questionable) if any of: shallow, large zenith angles, or flags 7-11

2 (cloud) if any input radiances are negative and saturated

3 (bad, other than cloud) if any input radiances are negative and not saturated, or Atmos Corr (bit 1 common flag) failed, or land

14-15 Mandatory Quality for Gordon's cocco_pig_c,cocco_conc,calcite_conc bands:

0 (good) if general bits are ok, and input Lw's are ok, and 13-15 are ok

1 (questionable) if any of: shallow, large zenith angles

2 (cloud) if any input radiances are negative and saturated

3 (bad, other than cloud) if any input radiances are negative and not saturated, or Atmos Corr (bit 1 above) failed, or land, or flags 13-15

16-17 Mandatory Qual for Hoge's peb and pub bands:

0 (good) if general bits are ok, and input Lw's are ok, and 17-21 are ok

1 (questionable) if any of: shallow, large zenith angles

2 (cloud) if any input radiances are negative and saturated

3 (bad, other than cloud) if any input radiances are negative and not saturated, or Atmos Corr (bit 1common flag) failed, or land, or flags 17-21

18 Cloudy - Albedo @ 865 > threshold 1=cloudy 0= clear

19-23 Spare

-flags - 3 bytes

0 =0 if pig_c input Lw's (9,12) are ok

1 =0 if Chl_A input Lw's (9,10,11,12) are ok

2 =0 if pig_total input Lw's (9,10,11,12) are ok

3 =0 if susp_solid input Lw's (9,10,11,12) are ok

4 =0 if k490 input Lw's (9,12) are ok

5 =0 if Abbott's Fluor baseline input Lw's (13,15) are ok

6 =0 if Abbott's FLH input Lw's (13,14,15) are ok

7 =0 if Fluorescence efficiency input Lw's (8-13) are ok

8 FLH_Range - FLH out of range

9 L748_High - L748 > L667

10 L678_Base - L678 peak below baseline

11 chlflag - Chlor < 2.0 mg/m^3

12 chlbad - Invalid chlor input

Gordon Cocco:

13 =0 if cocco input Lw's (flag 9,12) are ok

14 LoRadiance - value below lower bound of lookup table

15 HiRadiance - value above upper bound of lookup table

16 InvalidEntry - invalid data in lookup table

Hoge:

17 Hoge's peb,pub input Lw's (8-12) are ok

18-22 range_iop_flags[5]: 5 separate flags; one for each IOP to flag if any IOP is outside of an expected realistic range. *** If any one

of these flags is set, output IOPs are suspect.

23 Cloudy - Albedo @ 865 > threshold 1=cloudy 0= clear

MODOCL2B- 3 bytes of QA parameters:

-quality level - 1 byte

bits

0-1 Mandatory Quality for Carder's chlor_a_3,ag400,aphi675,atot_mod*:
0 (good) if general bits are ok, and input Lw's are ok, and 2-9 are ok
1 (questionable) if any of: shallow, large zenith angles, or flags 2-9
2 (cloud) if any input radiances are negative and saturated
3 (bad, other than cloud) if any input radiances are negative and not saturated, or Atmos Corr (bit 1 above) failed, or land, or flag 1

2-3 Mandatory Quality for Carder's ipar and arp bands:
0 (good) if general bits are ok, and input Lw's are ok, and 1,11 ok
1 (questionable) if any of: shallow, large zenith angles, or flag 11
2 (cloud) if any input radiances are negative and saturated
3 (bad, other than cloud) if any input radiances are negative and not saturated, or Atmos Corr (bit 1 common flag) failed,or land,or flag 1

4-7 Spare

-flags - 2 bytes

Carder Chlorophyll:

0 =0 if input Lw's (8-13) for Carder's bands are ok

1 neg_rrs_flag - one or more rss are less than or equal to zero

2 low_412_flag - rss[0](412) less than thresh_412

3 low_555_flag - rss[4](555) less than thresh_555

4 default_flag - using default chlorophyll model

5 chl_inconsistent_flag - calc chl exceeds chl_incon._thresh

6 chl_quality_flag - (currently unused)

7 hi_scat_flag - (currently unused)

8 blend_flag - aph_mod between .03 and .06 chlor. blend

9 package_flag - chl package or unpackage

Carder PAR:

10 =0 if ipar,arp input Lw's (8-13) are ok

11 hi_windspeed - wind speed > threshold

12 Cloudy - Albedo @ 865 > threshold 1=cloudy 0= clear

13-15 Spare

MODSSTL2 3 bytes:

-quality - 1 byte

0-1 Mandatory Qual ity for SST products:

0 (good) if general bits are ok, and input Lw's are ok, and 2-7 are ok

1 (questionable) if any of: shallow, large zenith angles, or flags 2-7

2 (cloud) if any input radiances are negative and saturated

3 (bad, other than cloud) if any input radiances are negative and not saturated, or Atmospheric Correction failed, or land.

2-3 Mandatory Qual for sst4 band:

0 (good) if general bits are ok, and input Lw's are ok, and 8-13 are ok

1 (questionable) if any of: shallow, large zenith angles, or flags 8-13

2 (cloud) if any input radiances are negative and saturated

3 (bad, other than cloud) if any input radiances are negative and not saturated, or Atmos Corr (bit 1 common flag) failed, or land

4-7 Spare

-flags - 2 bytes

0	=0 if sst input Lw's (20,31,32) are ok
1	=0 if sst4 input Lw's (20,22,23) are ok
2	ch31/32 uniformity test 1
3	ch31/32 uniformity test 2
4	ch31/32 zenith angle 1
5	ch31/32 zenith angle 2
6	ch31/32 tree test
7	ch31/32 sst diff from reference
8	ch20/31/32 brightness temps ok
9	ch22/23 uniformity test 1
10	ch22/23 uniformity test 2
11	ch22/23 zenith angle 1
12	ch22/23 zenith angle 2
13	ch22/23 out come of tree model tests
14	ch22/23 sst different from reference
15	ch20/22/23 brightness temps ok

Pixel Level L3 QA parameters

All pixel QA flags present the L2* files are stored in each of the 40 MOCEAN L3 products. Only the Quality level associated with a particular product is written to a given L3 daily parameter product file. For example for MODOC* there are 3 L2 files which are binned into 36 different L3 daily products, all L2 flags bits are stored in each of the 36 L3 files, however, a given L3parameter file will only store the quality level associated with that product, not all quality levels that were present in the L2 file from which it originated. A level-3 product at reduced resolution, say 4.2km, will contain only one set of flags per bin, not multiple sets representing each level 2 1km pixel. The methodology for collapsing these flags is to bin only the highest quality pixels available within the 4km's. If a particular flag bit is set for one of the 1km pixels summed into the 4km bin then the equivalent flag bit is set for the 4km bin.

6. 2Granule/Product level QA parameters:

The MOCEANS QA protocol will make use of the ECS QA inventory metadata **Science quality flag** to communicate and summarize the status of QA procedures. The value and updates of the **Science quality flag** is coordinated by the MODAT manager located at the RSMAS SCF. The ECS **Science quality flag** can hold the following values.

Not Investigated- which is the default value set by the PGE at execution.
Being Investigated - indicating that MODAT is examining the granule or product and suspects a problem
Failed - indicates the granule failed QA analysis and the problem has been solved and the granule or product will require reprocessing.
Passed- indicates passed or inferred pass of science post run time QA procedures
Validated - passed long-term validation analysis and comparison with matchup databases

Frequent updates to the ECS metadata QA parameters are anticipated as a suspected granule moves through the QA procedure end to end. The MODAT manager will coordinate with the Science team all ECS inventory metadata updates and keep a history of QA results and updates for all oceans granules produce in the MOCEANS QA database.

7.0 Summary

This document describes the MOCEAN quality assurance plan**.** MOCEAN QA procedures will be performed shortly after product generation (processing context QA) and some period after product generation at the MOCEAN RSMAS SCF and team member institutions (post run time science and validation QA). A MODIS OCEAN QA facility (MODAT) has been formed to provide a coordination mechanism for MOCEAN QA activities. The goal of MOCEAN QA activities is to understanding differences due to instrumental, code/algorithm, geophysical, and biological effects. The QA protocol developed is adaptive enough to accommodate a changing QA data stream over the life of MOCEAN while satisfying the needs of the algorithm developers, personnel performing routine QA of generated products, and the data users. The protocol includes examination of both production information and pixel level QA results stored in science data sets (SDS) generated at the time of execution (non-searchable) to perform processing and post run-time science QA. The status of QA results for a

granule/product will be communicated by frequent updates to searchable granule/product level ECS QA inventory metadata as a granule/product moves end-end through the QA procedures.